

ABUNDANCE OF SOARING RAPTORS IN THE BRAZILIAN ATLANTIC RAINFOREST

SANTI MAÑOSA,¹ EDUARDO MATEOS, AND VITTORIO PEDROCCHI

Departament de Biologia Animal, Universitat de Barcelona, Facultat de Biologia, Avinguda Diagonal, 645, 08028 Barcelona, Catalonia, Spain

ABSTRACT.—18 August–4 September 1998, we conducted 23 3–4 hr point-counts in an Atlantic rainforest area of southeastern Brazil to evaluate the richness and relative abundance of raptors in two adjacent protected areas, Parque Estadual Intervales and the Parque Estadual Turístico do Alto Ribeira. During 88.2 hr, we recorded 334 contacts with raptors, involving 734 individuals of nine species. Contacts per hour and the number of species tallied showed that the counts were higher between 0900–1200 H (Local Standard Time), and that counts of 3 hr were the most cost effective. Reasonable precision for abundance indices was achieved with samples sizes of 20–30 points, but samples of 12 should give satisfactory results for the more common species, as long as counting points are distributed sufficiently in space. We derived abundance indices for species of raptors most commonly seen in the area. In 14 3-hr counts, Black Vultures (*Coragyps atratus*) were observed in 100% of them, Mantled Hawks (*Leucopternis polionota*) in 71%, Black Hawk-Eagles (*Spizaetus tyrannus*) in 50%, Turkey Vultures (*Cathartes aura*) in 29%, Ornate Hawk-Eagles (*Spizaetus ornatus*) in 21%, Roadside Hawks (*Buteo magnirostris*) in 14%, Short-tailed Hawks (*Buteo brachyurus*) in 14%, Crested Caracaras (*Polyborus plancus*) in 14%, and Tiny Hawks (*Accipiter superciliosus*) in 7%. Bat Falcons (*Falco rufigularis*) and White-tailed Hawks (*Buteo albicaudatus*) also were reported in the area, but outside the counting periods.

KEY WORDS: Brazilian rainforest; point count; richness; São Paulo State.

ABUNDANCIA DE RAPACES PLANEADORAS EN LA SELVA ATLÁNTICA BRASILEÑA

RESUMEN.—Entre el 18 de agosto–4 de septiembre de 1998, realizamos 23 censos puntuales de 3–4 hr de duración en la selva Atlántica del Brasil, para estimar la riqueza y abundancia de aves de presa en dos zonas protegidas adyacentes, el Parque Estadual Intervales y el Parque Estadual Turístico do Alto Ribeira. Tras 88.2 hr de censo se obtuvieron 334 observaciones de rapaces correspondientes a 734 individuos de 9 especies. El número de contactos y de especies observadas indican que la mejor hora para realizar los censos se sitúa entre las 0900–1200 H (Hora Local Time) y que su duración óptima es de 3 hr. Una buena precisión en las estimas de abundancia se obtiene a partir de tamaños muestrales de 20–30 puntos, pero muestras de 12 puntos pueden ofrecer resultados satisfactorios para las especies más frecuentes, siempre y cuando los puntos se encuentren bien repartidos por el área de estudio. En catorce censos de tres horas llevados a cabo entre las 0900–1200 H, el Zopilote Negro (*Coragyps atratus*) se observó en el 100% de los censos, el Busardo Blanquinegro (*Leucopternis polionota*) en el 71%, el Aguila-Azor Negra (*Spizaetus tyrannus*) en el 50%, el Aura Gallipavo (*Cathartes aura*) en el 29%, el Aguila-Azor Galana (*Spizaetus ornatus*) en el 21%, el Busardo Caminero (*Buteo magnirostris*), el Busardo Colicorto (*Buteo brachyurus*), el Caracara Carancho (*Polyborus plancus*) en el 14%, y el Gavilancito Americano (*Accipiter superciliosus*) en el 7% los casos. El Halcón Murcielaguero (*Falco rufigularis*) y el Busardo Coliblanco (*Buteo albicaudatus*) fueron observados fuera de los períodos de censo.

[Traducción de los Autores]

The Atlantic rainforest of Brazil is one of the most threatened biomes in the world. Only 2–8% of the 10⁶ km² of forest that once covered a narrow stretch of land along the southeastern coast of Brazil remains in scattered, small fragments (Fonseca

1985, Albuquerque 1995, Myers et al. 2000). One of the best-preserved areas of Atlantic rainforest is the Paranapiacaba forest fragment (140 000 ha) (Mateos et al. 2002). This fragment includes some areas of unprotected forest and four protected areas (Parque Estadual Turístico do Alto Ribeira, Parque Estadual Intervales, Parque Estadual Carlos

¹ E-mail address: srife@bio.ub.es

Botelho, and Estação Ecológica Xitué) known as the Paranapiacaba Ecological Continuum (Pisciotta 2002), which, all together, form one of the largest remaining patches of uninterrupted Atlantic rainforest (Fig. 1).

In spite of its fragmentation, the Atlantic rainforest remains among the richest of all ornithological areas in the world (Cracraft 1985, Wege and Long 1995, Stattersfield et al. 1998) and is considered a hotspot for biodiversity conservation (Myers 1988, Bibby et al. 1992b, Myers et al. 2000). The area gives refuge to many endemic birds (Myers et al. 2000), among which are several species and subspecies of raptors such as Grey-headed Kites (*Lepidodon cayanaensis*), White-necked Hawks (*Leucopternis lacernulata*), Mantled Hawks (*Leucopternis polionota*), and Black Hawk-Eagles (*Spizaetus t. tyrannus*) (Collar et al. 1992, del Hoyo et al. 1994, Bierregaard 1998, Bildstein et al. 1998). This justifies the need for scientific and conservation initiatives to protect this important element of the global biodiversity (Burnham et al. 1994).

Raptors usually live at low densities and are difficult to detect, so that the methods usually employed to evaluate general bird populations are not adequate (Forsman and Solonen 1984, Thiollay 1989, Bibby et al. 1992a). Accurate species richness and abundance estimates require surveying large areas and conducting a large number of counts. The dense structure of the rainforest adds even more difficulty to the study of these raptors (Thiollay 1989), and a great deal of time and effort are often required to prepare and to conduct the counts (Whitacre and Turley 1990, Mañosa and Pedrocchi 1997).

For these reasons, the conservation status of many woodland raptors in the neotropics is poorly known (Albuquerque 1986, Thiollay 1994), in spite of the fact that more than half of the species of neotropical raptors are endangered (Thiollay 1985, Bildstein et al. 1998). Several research and monitoring programs are currently providing new information about raptors in tropical forests (Thiollay 1989, Vannini 1989, Whitacre and Thorstrom 1992), but only preliminary research has been conducted in the Atlantic rainforest (Willis and Oniki 1981, Guix et al. 1992, Mateos and Mañosa 1996, Mañosa and Pedrocchi 1997, Veilliard and Silva 2001, Mañosa et al. 2002).

Considering the need of improving our knowledge on raptor assemblages in Atlantic rainforest areas, as well as the need of achieving maximum

accuracy of the results and efficiency of the counting effort, the objectives of our research were (1) to evaluate the effect of several variables (time of day, duration of counts, number of counts, selection of counting points) on the efficiency of the point-count method in estimating species richness and abundance indices of raptor assemblages in the Atlantic rainforest, and (2) to derive the best estimate of abundance indices of raptors in a well-preserved area of Brazilian Atlantic rainforest.

MATERIAL AND METHODS

Study Areas. Counts were conducted in two adjacent areas of the Parque Estadual Turístico do Alto Ribeira (Petar) and the Parque Estadual Intervales (Intervales), within the Paranapiacaba forest fragment in Serra do Mar mountain range, in the state of São Paulo, Brazil (Fig. 1). The Serra do Mar extends parallel to the Atlantic coast for over 900 km. Its slopes rise to abrupt mountain peaks between 800–1100 m in elevation. The Paranapiacaba forest fragment (Pisciotta 2002) consists of four legally-protected, neighboring reserves, known as the Paranapiacaba Ecological Continuum (1258 km²), plus some adjacent private forest areas. Together, they comprise some 1400 km² of uninterrupted forest in several ecological successional stages (Fig. 1). Most of the Paranapiacaba forest fragment is covered by Low Elevation South Hillside Atlantic rainforest (Guix 2002), typical of the altitudinal range between 50–100 m and 1200–1600 masl, and tree height ranging from 20–30 m. Some surrounding and marginal areas (near 10% of the total area) is planted *Araucaria angustifolia*, *Pinus* sp. and *Eucalyptus* sp. forest, banana plantations, and pastures. Four main vegetation types can be distinguished in the Paranapiacaba forest fragment: mature forests, which have been subject to no episode of deforestation or intensive selective extraction, or only a single one more than 80–100 yr ago; late-secondary forests, which suffered the last episode of deforestation or intensive selective extraction 50–80 yr ago; young-secondary forests, which suffered the last deforestation or selective extraction episode 20–40 yr ago; and “capoeiras” or shrublands, which are forest areas that have undergone the last deforestation episodes just 5–15 yr ago. The study area is covered by mature and secondary forest types. In some zones of shallow calcareous soil in the Petar site, mature or late-secondary forests are lower in stature than those of the same successional stages in Intervales.

The study area in Intervales was the main valley of the Formoso-Pilões River, from just above Base do Carmo to a few kilometers beyond Base do Alecrim (Fig. 1). The Atlantic rainforest in this valley is mature or late-secondary, with a mean height of 18 m and emergent trees reaching 24–30 m. Palmito (*Euterpe edulis*) is abundant but becomes scarcer at the bottom of the valley, where taquara (*Merostachys* sp.) is widespread. On mountain sides and summits and facing north northwest, the Atlantic rainforest is most intact and there is hardly any taquaral present. On the highest areas of the valley, near Base do Carmo, human influence is minimal or nonexistent: mature or old-secondary forests cover the region.

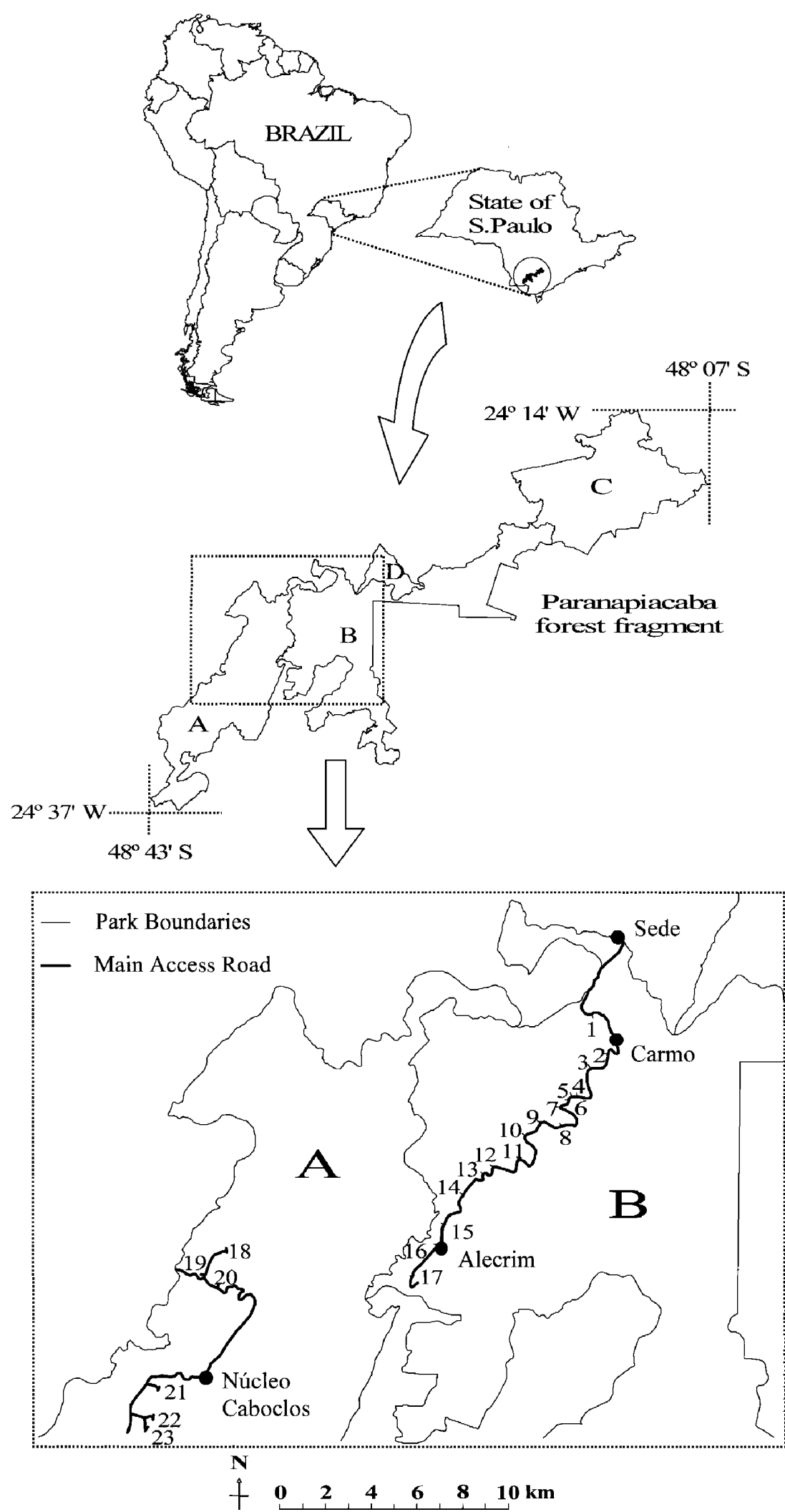


Figure 1. Location of the study area in Brazil. The limits of the four protected areas conforming the Ecological Continuum of the Paranapiacaba forest fragment within the São Paulo State are indicated. (A: Parque Estadual Turístico do Alto Ribeira; B: Parque Estadual, Intervales; C: Parque Estadual, Carlos Botelho; D: Estação Ecológica Xitué). The study area is outlined and enlarged, showing the location of the 23 counting points indicated by the numbers.

“Capoeiras” occur only along the main road and trails, due to the extraction of palmito palms and wood. The valley bottom near Alecrim has been inhabited and modified for centuries. Late-secondary forest dominates this region, with a scattering of small banana plantations. Taquaral areas around Alecrim are the remains of opened areas used for subsistence farming 15–25 yr ago.

The study area in Parque Estadual Turístico do Alto Ribeira was adjacent to the village of Núcleo Caboclos (Fig. 1). The Núcleo Caboclos is 600 masl and is covered by typical Hillside Atlantic rainforest vegetation (Carvalho et al. 2002) with a high botanical diversity. This high diversity is caused by the existence of calcareous sediments that enhance the growth of forests with a particular floristic composition. Secondary vegetation grows in the margins of dirt tracks and trails; it is characterized by taquaral and shrublands.

Field Procedures. The point-count method (Whitacre and Turley 1990, Whitacre et al. 1992a) was used because it was the most effective method in a preliminary survey in 1994 (Mañosa and Pedrocchi 1997). Counts were conducted during the dry season, between 18 August and 4 September 1998, when some raptors (i.e., Mantled Hawk, Black Hawk-Eagle) are expected to be displaying in the area (Vielliard and Silva 2001). One or two observers stayed on high points of the landscape or perched on the tops of trees, having a view angle of 80–294° and a range of view above the canopy of 1000–4000 m. We selected 23 points along main tracks or footpaths (Fig. 1), which we judged to be representative of the dominant habitat in the area. Seventeen of these points were along 27 km of the Formoso-Pilões Valley and six around the Caboclos area. Each point was selected in order to give an independent view of a part of the study area. The mean distance between neighboring points was 997 ± 441 m (SD) in Intervalles (range = 267–1493) and 1900 ± 1665 m in Petar (range = 600–5161). Even the closest points offered non-overlapping views of the study area. The counts were initiated between 0800–1200 H (Local Standard Time, sunrise 0519 H), and lasted for 2.5–4 hr. The mean length of the counts was 3.8 ± 0.4 hr (SD). Each point was sampled only once. The 23 counts totalled 88.2 hr of observation, concentrated from 0900–1300 H (72.1 hr). Counts were conducted in clear weather, except for one that was conducted in light rain but yielded comparable results. During each count interval, we recorded every raptor in view to an unbounded distance. In this manner, we obtained a list of the minimum number of individuals and groups observed during every count.

Computation of Relative Abundance Parameters. We computed the following abundance indices for each species and area: percentage of counting points in which a species was detected (percent presence $\pm 95\%$ Confidence Interval [CI]), mean group size (individuals \pm SD), and contacts/hr ($\pm 95\%$ CI). Confidence intervals were computed by bootstrap techniques, using the *Resampling Stats* suite (Bruce et al. 1995): a parameter value was computed for each original counting point. This gave an initial sample of values, which was randomly resampled with replacement to obtain a sample size identical to the original one. This process was repeated 10 000 times. Then, the mean and confidence intervals of the 10 000 parameter estimates were obtained.

Evaluation of Biases. The effect of the time of day (morning only) on the results of the counts was evaluated by analyzing the number of species reported at several hourly intervals. For species in which the number of observations was large (Mantled Hawk, Black Vulture, Turkey Vulture, and Black Hawk-Eagle), an hourly reporting pattern was also obtained. An index of activity was computed for each hourly interval and species. Each hourly period of observation was divided into twelve 5-min intervals. During each interval, we recorded the number of individuals in view. The activity index for a given species during a specific hourly interval was the product of the proportion of 5-min intervals in which the species was in view during that period (from 0/12–12/12) by the addition of all individuals recorded during the twelve 5-min intervals.

To assess the optimal duration of counts, we analyzed how the number of detected species and abundance indices estimates changed in relation to count duration. We limited this analysis to the counts initiated at 0900 H and that were extended to 1300 H ($N = 9$), so that the effect of sampling at different times of day was removed.

The relationship between precision of estimates and sample size was modelled using bootstrapping techniques (see above) by taking samples of progressively increasing size (1–50). To evaluate how the precision of the abundance indices improved with sample size, the $\pm 95\%$ CI of these estimates were plotted against the number of counts. To make comparisons between parameters and species possible, precision was expressed as (upper 95% CI – lower 95% CI)/mean.

To test how the selection of the counting points could affect the results, we divided our initial set of 23 points into two sets of spatially alternating points, a set of 12 (set A) and a set of 11 (set B) points. These two data subsets were used to derive two separate estimates of the relative-abundance parameters. Comparison between these two sets should give some indication of the reproducibility and accuracy of our results.

Computing Standard Abundance Estimates. Standardized abundance indices estimates of raptors for the study area as a whole and for each of the two Preserve Areas were derived, considering only the 14 counts in the 0900–1200 H period. The remaining nine counts were omitted because they lasted for less than three hours or because they did not include the above-mentioned period.

RESULTS

We recorded 11 raptor species in the Paranapiacaba forest fragment, two of which, the Bat Falcon (*Falco rufigularis*) and the White-tailed Hawk (*Buteo albicaudatus*), were observed for the first time in the area (Table 1). The 23 counts yielded 334 observations of raptors (3.8 contacts/hr) involving 734 individuals, belonging to nine species of raptors (Table 2). Only one of the 23 counts (4%) resulted in no raptor observations, four yielded one species, five yielded two species, four yielded

Table 1. Composition of the raptor assemblage in the Paranapiacaba forest fragment, according to the species recorded in several surveys to the area. “x” indicates the species was recorded outside the primary sample periods. Vagrant species, as well as migratory species that are absent from the area in August, are excluded.

| | WILLIS AND ONIKI (1981) ^a | VIELLIARD AND SILVA (2001) ^b | MAÑOSA ET AL. (1997) ^c | This study ^d |
|---|---|---|---|----------------------------|
| Black Vulture (<i>Coragyps atratus</i>) | 49 | 100% | 50% | 100% |
| Turkey Vulture (<i>Cathartes aura</i>) | | 59% | x | 29% |
| Grey-headed Kite (<i>Leptodon cayanensis</i>) | | 9% | ? | |
| Rufous-thighed Kite (<i>Harpagus diodon</i>) | | 18% | | |
| Grey-bellied Goshawk (<i>Accipiter poliogaster</i>) | | 14% | | |
| Tiny Hawk (<i>Accipiter superciliosus</i>) | | | 25% | 7% |
| Sharp-shinned Hawk (<i>Accipiter striatus</i>) | | x | | |
| Crane Hawk (<i>Geranospiza caerulescens</i>) | | x | | |
| Mantled Hawk (<i>Leucopternis polionota</i>) | 2 | 86% | 50% | 71% |
| Great Black-Hawk (<i>Buteogallus urubitinga</i>) | | 4% | | |
| Black-chested Buzzard-Eagle (<i>Geranoaetus melanoleucus</i>) | | x | | |
| Roadside Hawk (<i>Buteo magnirostris</i>) | 34 | 95% | x | 14% |
| White-rumped Hawk (<i>Buteo leucorrhous</i>) | 2 | x | | |
| Short-tailed Hawk (<i>Buteo brachyurus</i>) | 7 | 54% | x | 14% |
| White-tailed Hawk (<i>Buteo albicaudatus</i>) | | | | x |
| Guiana Crested Eagle (<i>Morphnus guianensis</i>) | | x | | |
| Black Hawk-Eagle (<i>Spizaetus tyrannus</i>) | | 68% | x | 50% |
| Ornate Hawk-Eagle (<i>Spizaetus ornatus</i>) | | | 25% | 21% |
| Crested Caracara (<i>Polyborus plancus</i>) | 2 | 18% | | 14% |
| Chimango Caracara (<i>Milvago chimachima</i>) | 17 | 54% | x | |
| Laughing Falcon (<i>Herpetotheres cachinnans</i>) | 5 | x | | |
| Barred Forest-Falcon (<i>Micrastur ruficollis</i>) | 10 | 77% | | |
| Collared Forest-Falcon (<i>Micrastur semitorquatus</i>) | | 4% | x | |
| Bat Falcon (<i>Falco ruficularis</i>) | | | | x |

^a Individuals/100 hr observation (*N* = 41.2 hr) reported in the Carlos Botelho area between 24–28 February and 5–10 July 1979 (Swallow-tailed Kite [*Elanoides forficatus* excluded]).

^b Percent of 22 visits to the Intervalles area between August 1988 and December 1992 in which the species were reported. “x” indicates presence during other occasional visits to the area (Osprey [*Pandion haliaetus*], Swallow-tailed Kite, and Plumbeous Kite [*Ictinia plumbea* excluded]).

^c Percent of point counts (*N* = 4) in which the species was detected during a visit to Intervalles between 1 and 12 August 1994. “x” indicates detection outside the counts.

^d Percent of point counts (*N* = 14) in which the species was detected during a visit to Intervalles and the Petar in August–September 1998. “x” indicates detection outside the counts.

^e Identification was uncertain.

three species, six yielded four species, and three yielded five species.

Effect of Time of Day. Only Mantled Hawks and Roadside Hawks (*Buteo magnirostris*) were observed before 0900 H. Although observation effort was minimal, only Black Vultures were consistently observed during the afternoon (1300–1600 H). The activity of this species remained more or less constant from 1000 H onwards (Fig. 2). Comparatively, the activity of Turkey Vultures was more concentrated around mid-day. Activity of Mantled Hawks remained constant during the morning and early

afternoon, whereas the activity of Black Hawk-Eagles tended to be maximum between 0900 and 1200 H. Overall, the period 1000–1200 H embraced the peak activity periods of the three most common species, as well as all the observations of Short-tailed Hawks (*Buteo brachyurus*). A high percentage of the records of the less detectable species, such as Tiny Hawks (*Accipiter superciliosus*, 100%, *N* = 1), Crested Caracaras (*Polyborus plancus*, 50%, *N* = 2), and Ornate Hawk-Eagles (*Spizaetus ornatus*, 50%, *N* = 4) were concentrated between 0900 and 1000 H.

Table 2. Raptor abundance indices in Parque Estadual Intervalles, Parque Estadual Turístico do Alto Ribeira and pooled estimate. Means and $\pm 95\%$ Confidence Intervals are given in parenthesis. *N* is the number of counts.

| | INTERVALES (<i>N</i> = 9) | PETAR (<i>N</i> = 5) | POOLED (<i>N</i> = 14) |
|--------------------------|-------------------------------|--------------------------|----------------------------|
| Hours of observation | 27 | 15 | 42 |
| Number of species | 8 | 8 | 9 |
| Black Vulture | | | |
| Contacts/hr | 2.5 (1.5–3.7) | 3.3 (2.3–4.2) | 2.8 (2.0–3.6) |
| Percent presence | 100 (100–100) | 100 (100–100) | 100 (100–100) |
| Mantled Hawk | | | |
| Contacts/hr | 0.7 (0.3–1.3) | 0.8 (0.4–1.2) | 0.8 (0.4–1.2) |
| Percent presence | 67 (33–100) | 80 (40–100) | 71 (50–93) |
| Black Hawk-Eagle | | | |
| Contacts/hr | 0.6 (0.1–1.2) | 0.7 (0.1–1.4) | 0.6 (0.2–1.1) |
| Percent presence | 44 (11–78) | 60 (20–100) | 50 (21–79) |
| Turkey Vulture | | | |
| Contacts/hr ^a | <0.1 (0.0–0.1) | 0.5 (0.1–0.8) | 0.2 (0.05–0.4) |
| Percent presence | 11 (0.00–33) | 60 (20–100) | 29 (7–57) |
| Roadside Hawk | | | |
| Contacts/hr | 0.2 (0.0–0.6) | 0.1 (0.0–0.2) | 0.1 (0.0–0.4) |
| Percent presence | 11 (0–33) | 20 (0–60) | 14 (0–36) |
| Ornate Hawk-Eagle | | | |
| Contacts/hr | <0.1 (0.0–0.1) | 0.1 (0.0–0.3) | 0.1 (0.0–0.1) |
| Percent presence | 11 (0–33) | 40 (0–80) | 21 (0–43) |
| Short-tailed Hawk | | | |
| Contacts/hr | 0.0 | 0.2 (0.0–0.5) | 0.1 (0.0–0.2) |
| Percent presence | 0 | 40 (0–80) | 14 (0–36) |
| Crested Caracara | | | |
| Contacts/hr | <0.1 (0.0–0.1) | 0.1 (0.0–0.2) | 0.05 (0.0–0.1) |
| Percent presence | 11 (0–33) | 20 (0–60) | 14 (0–36) |
| Tiny Hawk | | | |
| Contacts/hr | <0.1 (0.0–0.1) | 0.0 | 0.02 (0.0–0.1) |
| Percent presence | 11 (0–33) | 0 | 7 (0–21) |

^a Significant differences between areas at *P* < 0.05; Kruskal-Wallis test.

Effect of Count Duration. The number of species observed ($\pm 95\%$ CI) tended to increase as the duration of the counts increased from 1 hr (1.4 ± 0.5 species) to 2 hr (2.7 ± 0.9), but leveled off progressively for 3 hr (3.0 ± 0.9) and 4 hr counts (3.2 ± 1.0). Among the four more frequent species, the cumulative percentage of counts levelled off after 2–3 hr of sampling for the Black Vulture and the Black Hawk-Eagle. For the Turkey Vulture and the Mantled Hawk, this parameter increased slightly, although not significantly, during the fourth hour of the count (Fig. 3).

Effect of the Number of Counts. The number of species detected increased quickly with the number of counts. Some 20 counts were needed to detect 90% of the total species documented, but the rate of addition of new species was low with the addition of more counts (Fig. 4). Precision of abundance indices estimates quickly increased with sample size (Fig. 5). For the more frequent species (i.e., percent presence 70–100%: Black Vultures, Mantled Hawks), the precision of the abundance estimates falls below one $\pm 95\%$ CI of the mean after 12 counts. For species with <30% presence

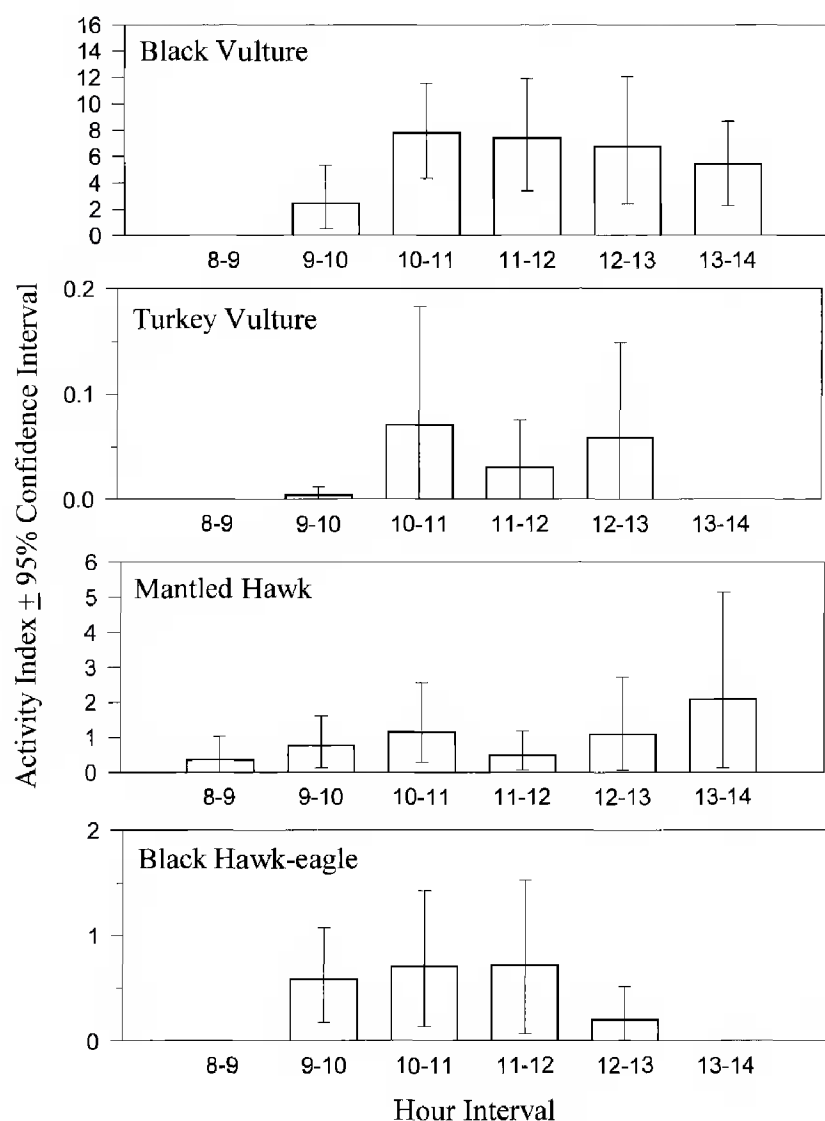


Figure 2. Hourly variation (Local Standard Time) of the activity index of the most common species in the study area (both sites combined). For a given hour period, the activity index for each species was computed as the product of the proportion of 5-min intervals in which the species was in view by the total number of individuals observed. Sunrise = 0519 Local Standard Time.

(i.e., Turkey Vulture), more than 50 samples are needed to reach such a precision value. However, the rate of increase in precision of parameter estimates is very low after 10–20 counts. At any given sample size, percent presence was slightly more precise than contacts/hr.

Reproducibility of Results. For the data set including all the counting points the mean distance between neighboring points (SD) was 1.2 ± 1.0 km (range = 0.3–5.2 km). For the two subsets of alternating points, these distances increased to 2.4 ± 1.3 km (range = 0.8–6.0 km) for subset A and 2.4 ± 1.6 km (range = 0.5–6.45 km) for subset B. Only the three most common species were detected in both subsets that, because of small sample size, yielded only five and six species, respectively. Abundance indices estimates based on these separate data sets had larger confidence intervals than es-

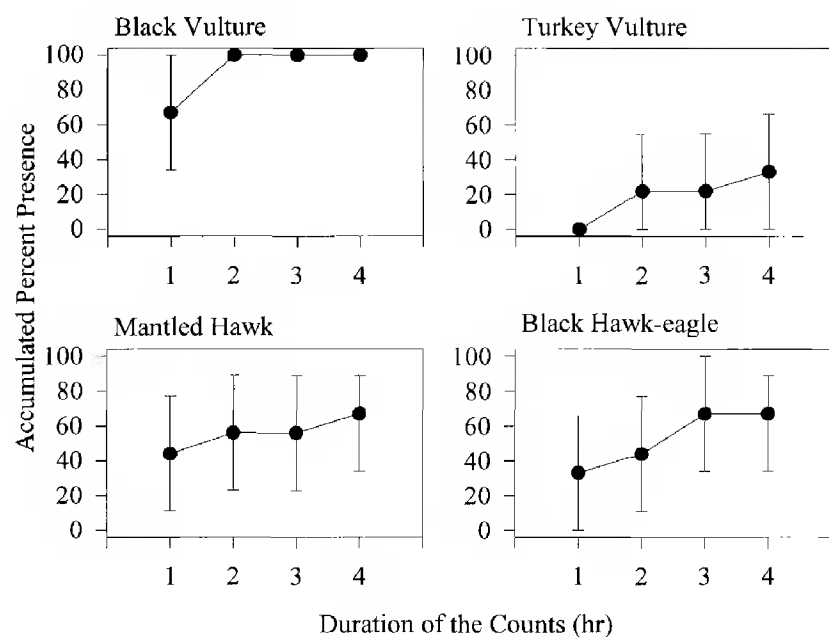


Figure 3. Simulation of cumulative percent presence of the most frequently-detected species in relation to the duration of counts (hr). All counts began at 0900 H. Computations are based on the same nine point counts

timates from the overall sample, but were not significantly different from one another, nor from the pooled estimate.

Composition of the Raptor Assemblage. During the fourteen standardized counts conducted between 0900 H and 1200 H, nine raptor species were detected (Table 2) of the 24 that have been reported in the area in this and in previous surveys (Willis and Oniki 1981, Mañosa and Pedrocchi 1997, Vielliard and Silva 2001; Table 1). Four species are reported in the four lists, four species in three, six species in two, and 10 species in only one. Of the 15 potential species which were missed in our point counts, only five had been reported

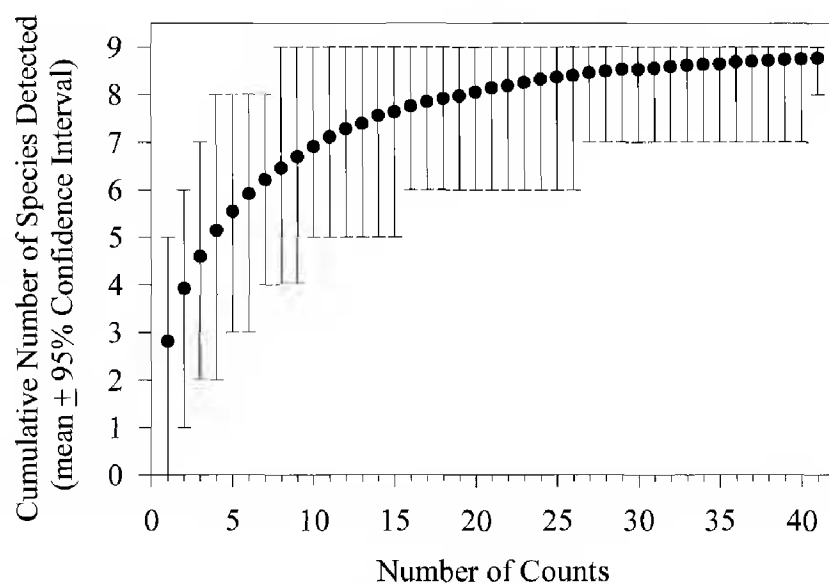


Figure 4. Simulation of the cumulative number of species detected in relation to the number of counts.

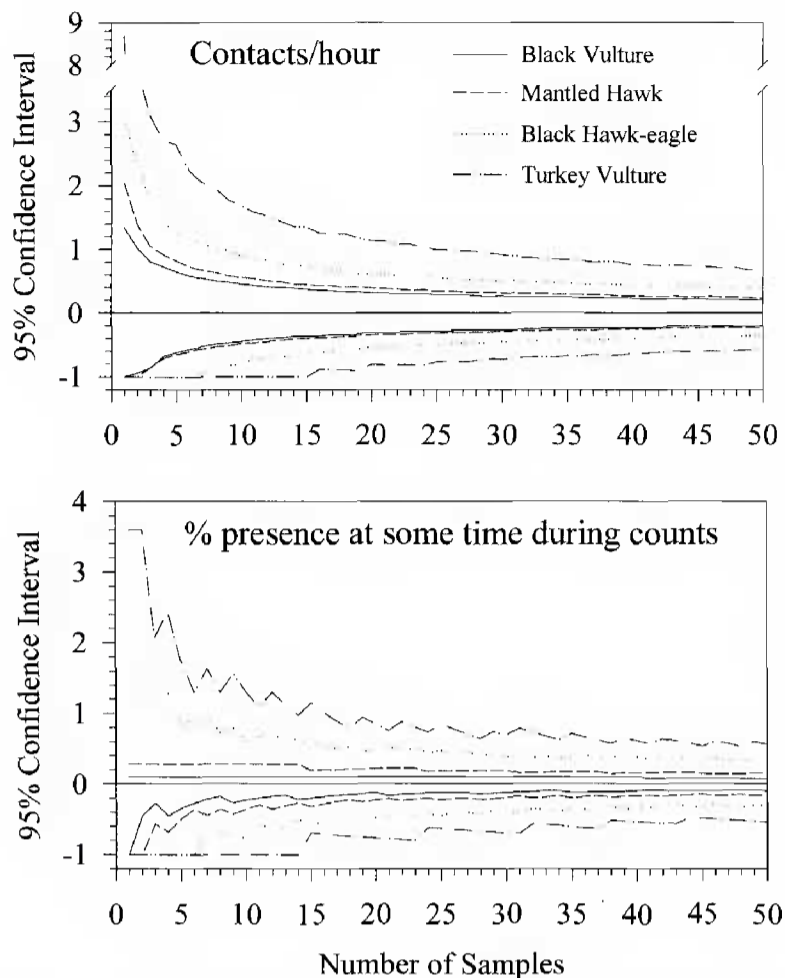


Figure 5. Simulation of the increase in precision of estimates around the means (mean = 0) of contacts/hour and percent presence estimates in relation to number of counts for the four most common species in the area. The $\pm 95\%$ Confidence Interval of the mean is expressed as multiples of the mean (Upper 95% Confidence Interval – Lower 95% Confidence Interval/Mean) and plotted against sample size.

in more than one previous survey, and only one species in more than two studies (Table 1).

The results of the fourteen standardized counts (Table 2) indicated that the Black Vulture was the most frequently detected species, involving 118 (59%) contacts. The species was usually observed flying in groups of 2–12 individuals (2.6 ± 1.7 birds/group). Only 26% of the observations of this species involved single birds. Mantled Hawks accounted for 31 (16%) contacts with groups of 1 or 2 birds (1.2 ± 0.4 birds/group). Black Hawk-Eagles involved 26 (13%) contacts of single birds or pairs (1.2 ± 0.4 birds/group). The remaining species each accounted for less than 5% of the records.

Both preserve areas showed similar species composition, but among the species with more than one record, the Short-tailed Hawk was reported only in Petar. All species tended to be more abundant in Petar than in Intervales (Table 2), al-

though the difference was only significant for the Turkey Vulture.

DISCUSSION

The timing, duration, efficiency of, and number of point counts is important in obtaining an optimal balance between sampling effort and an adequate description of raptor assemblages. If extended count periods do not result in the detection of more species, then additional time would be best invested in sampling a larger area or searching and installing additional points. Within a counting point, time should be limited to that needed to detect all species active on a given morning. In our counts, every few species were detected before 0900 H, whereas, after 1200 H detection frequency of most raptors, including the Black Hawk-Eagle, declined. Counts of less than 3 hr duration had a high probability of missing some species, but after three counting hours, no new species were detected. Also, for the common species, abundance indices stabilize after the third hour of the count. This indicates that the best cost-effective alternatives may be conducting 3-hr counts from 0900–1200 H (Local Standard Time), that is between 3 hr 41 min and 6 hr 41 min after sunrise, a bit later than what has been found in other rainforest areas (Whitacre and Turley 1990, Whitacre and Thorstrom 1992).

The number of counts is related to the number of species that would be detected (Whitacre and Turley 1990) and how well the raptor assemblage is characterized. It is also important in determining the precision of the abundance estimates (Bibby et al. 1992a). Accuracy and precision in monitoring programs is needed to detect small differences between years, habitats, or areas. However, after a certain level of precision is reached, further improvement can only be achieved at a high cost. Our results indicate that the more detectable species are found with few counts, but that sample sizes of 11–12 points may still miss some important, though less detectable, species. With 20 points, 90% of the more-detectable species are identified, but more than half the potential species present in the area are still missed (Table 1). On the other hand, 12 counts may provide abundance indices within one $\pm 95\%$ CI of the mean, but only for the two most common species (Black Vulture, Mantled Hawk). A minimum of 20–30 counts would be needed to obtain comparable precision for the next most frequently-detected species (Black

Hawk-Eagle). Precise abundance estimates for the still less detectable raptors would only be obtained at the expense of much more sampling effort (>50 counts), which also would be needed to detect additional species or to slightly improve the precision of the estimates of more common species.

Bias in the selection of counting points may also have an effect on the estimation of species richness and on the accuracy of abundance estimates. This bias can arise from selecting points not representative of the area being surveyed, or from excessive proximity of sampling points, which may result in double counting of territorial raptors. Comparison of two subsets of our data points suggests that for the most detectable species, species richness was little affected by the reduction of number and placement of counting points, and that relative abundance estimates were also not altered.

Counts were conducted at the start of the nesting season, when raptors were most active and probably when the point count method was most effective (Whitacre and Turley 1990). However, during the counts we only detected nine of the 24 species potentially present in the area (Table 1). Most of the remaining species seem to be relatively uncommon, but some may have been missed because of the timing of the counts. This may be the case of Grey-headed Kite (*Leptodon cayanensis*), which generally displays early in the breeding season (October, according to Vielliard and Silva [2001] and Whitacre pers. comm.). Small size may account for the absence from our list of Rufous-thighed Kite (*Harpagus diodon*), which was relatively frequent in some previous surveys. The point-count method may also overlook non-soaring species, which would explain why Tiny Hawks, Bat Falcons, forest-falcons (*Micrastur* sp.), and Crested Eagles (*Morphnus guianensis*) were not detected. For these species, the use of acoustical luring or pre-dawn listening may be more effective (Whitacre and Turley 1990).

Comparing all raptor surveys available from the area (Willis and Oniki 1981, Mañosa et al. 1997, Vielliard and Silva 2001; Table 1), the Black Vulture appears as the most common species. The Roadside Hawk emerged as the second most-frequently-detected species in Willis and Oniki (1981) and Vielliard and Silva (2001) studies, instead of the Mantled Hawk, which ranked second in our survey. This difference may indicate temporal changes in species abundance or, more likely, differences in the methods and habitats sampled.

These differences may also explain the surprising absence of the Ornate Hawk-Eagle from the Willis and Oniki (1981) and Vielliard and Silva (2001) surveys. On the other hand, we were unable to detect some species that may be relatively common in the area, such as forest-falcons and the Chimango Caracara (*Milvago chimachima*). Other raptor species we may have missed that have been reported from other Atlantic rainforest areas are the Bicolored Hawk (*Accipiter bicolor*) (Willis and Oniki 1981), the White-necked Hawk and the Harpy Eagle (*Harpyia harpyja*) (Albuquerque 1995).

The point count method provides only indices of species abundance rather than information on population densities. Theoretically, these measures should be related, but detectability may differ between species, so comparisons of detection rates are most reasonable between species of similar size and behavior (Thiollay 1989). Different soaring propensities, behavior, and body size of the different species largely affect detectability during point counts. This is especially true because we used an unlimited observation radius, which favors larger species at the expense of smaller ones. Thus, the point-count method may overestimate the abundance of larger and wide-ranging species (eagles, vultures) in relation to those of the smaller raptors (Jullien and Thiollay 1996).

Both the Intervales and Petar protected areas may support similar raptor assemblages, although some raptors, in particular the Turkey Vulture, tended to be more abundant in Petar than in Intervales. The relatively high abundance of open-country species reveals the effect of human settlement in the area and the relative proximity of open habitat near the preserves. In spite of this influence, the Mantled Hawk, an endemic species of the Atlantic rainforest, was found to be common in the area. Hawk-eagles also were common, particularly the Black Hawk-Eagle, a specialist of secondary or disturbed forest patches (Jullien and Thiollay 1996, Thiollay 1999). The Ornate Hawk-Eagle, which is thought to be restricted to little-disturbed forest (Jullien and Thiollay 1996), was less frequently observed than the Black Hawk-Eagle. This difference in detections of these two species may reflect the dominance of late-secondary forest in the area, but also the lower soaring propensity (del Hoyo et al. 1994) and detectability of Ornate Hawk-Eagle, even in areas where it is more abundant than the former species (D. Whitacre pers. comm.). Mean percent presence of hawk-ea-

gles was higher and the presence of *Buteo* hawks lower in the Paranapiacaba fragment than in several rainforest areas where raptor counts have been conducted in Central America (Jones and Sutter 1992, Whitacre et al. 1992b). Also, the Black Vulture may be relatively more abundant and Turkey Vulture less abundant than in the Central American study sites. These differences may indicate differences in habitats among areas or reflect different degrees of modification among sites.

The results of these counts confirm the importance of the ecological continuum of the Paranapiacaba fragment for the conservation of endangered raptors in the Brazilian Atlantic rainforest. The area supports relatively abundant populations of the Mantled Hawk, a poorly known species (Thiollay 1985, IUCN 1990), which is considered endangered (Thiollay 1994) or nearly endangered (Collar et al. 1992, del Hoyo et al. 1994). The relatively frequent detections of two other poorly-known species, the Ornate and the Black Hawk-Eagles (Bildstein et al. 1998), also is notable. Particularly as the subspecies of Black Hawk-Eagle, which was documented, is an endemic of the Brazilian Atlantic rainforest (Bierregaard 1998). Further fragmentation of the Paranapiacaba forest may severely impact populations of these poorly-studied species. Although changes on the populations of the rare or less detectable species may not be adequately tracked with this general point-count technique, standardization of the counting method would allow the implementation of monitoring programs with the objective to detect trends of some of the more detectable species, such as Mantled Hawks and hawk-eagles. Importantly, these species are of conservation concern and may be good indicators of habitat changes in the Atlantic rainforest relevant to the entire raptor assemblage.

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